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Irish Council for Science,
Technology and Innovation

Technology Foresight Ireland

Report of the Information and Communications Technologies Panel

Forfás

Established by the Government and Forfás to advise on Science, Technology and Innovation

Chairman's Acknowledgement

This report from the Information and Communication Technologies Foresight Panel comes at the end of a process that has involved a lot of hard work, but that has ultimately been stimulating and provocative.

The process was designed to open the minds of the participants, to help them see things from a fresh perspective, to look beyond the here and now, to consider the possible.

The process worked, because everyone involved immersed themselves in it, and gave freely of their time, energy, intellect and experience. It worked because they discarded their prejudices and their personal and organisational self interests, and considered the country's future, and the well-being of Irish society.

I was changed by the process, and felt privileged to work on such an important task with such a group of people. I would like to thank the Task Force members, and the others who participated in the process, for their commitment, enthusiasm, and, not least, their ideas -- ideas that have the power to create a new future.

I would also like to thank the Forfás secretariat, and Martin Hynes in particular, for facilitating the process so efficiently.

The report is the end of a process, but it is also a beginning. This report contains a small number of critical recommendations, and the Task Force is willing to work towards their implementation.

Paul Holden
Chair, ICT Foresight Panel

The Irish Council for Science, Technology and Innovation would like to acknowledge the valuable support and advice provided to all eight Panels and the Task Force both before and throughout the process by Hans Donkersloot, Ministry of Education, Culture and Science, The Netherlands; Eamonn Cahill, Irish Productivity Centre and James Gavigan, the EU Institute for Prospective Technological Studies, Seville.

Executive Summary

Information and Communications Technologies (ICT) have made a major contribution to recent economic growth in all developed countries. Ireland has benefited very significantly from these technologies, in terms of employment and wealth generation. These technologies will continue to be at the core of economic and social progress in the years ahead: according to a White House official, 'A third of all economic growth in the last several years has been due to information technology. Everybody from Wal-Mart to Wall Street is using it.' This comment was made in the context of a proposal to invest an additional $366 million in the year 2000 in ICT related research.

In Ireland, we are justifiably proud of our performance in the ICT area: we have attracted many of the world's leading companies to establish bases here and they have been convinced, by the quality of people and the industrial climate, to broaden the scope of their operations. We have built a vibrant indigenous industry and a number of indigenous companies have achieved very significant success on world markets.

However, these successes should not lull us into complacency: there are several weaknesses in the current industry structure that must be addressed if the industry is to prosper in the coming years and realise the potential benefits for Irish society.

In general, (and there are some notable exceptions), the ICT industry in Ireland is positioned at a relatively low point on the value chain: it deals in relatively mature technology that has been developed elsewhere.

In the years ahead, there will be intense competition at this end of the value chain. The main competitive factor will be cost and particularly labour cost. Ireland is unlikely to be able to compete on this basis: we need to increase the value-added component in our ICT products and services.

To do this, industry will need a cadre of world class professional researchers in the ICT disciplines – people who can contribute original marketable ideas, who can form the nucleus of new, world class companies, and who can attract a new kind of multinational investment. The current output of postgraduates (approximately 60 per annum with pertinent skills) is quite inadequate for this kind of development.

State investment in research is significantly lower than in most developed economies. As we move from an economy based on relatively low skill levels to one based on knowledge and expertise, our continued prosperity depends on substantially increasing this investment.

The efforts of the PATs (Programmes in Advanced Technology) and other RTI (research, technology and innovation) programmes have led to measurable benefits, but the current structures are incapable of developing teams with 'world class' scale or expertise. They are therefore unable to conduct the type of research that will attract international attention, bring in significant industrial investment, or routinely spin off high technology, market leading enterprises.

Centre for Advanced Informatics

The core recommendation from the Panel is to establish a Centre for Advanced Informatics in ICT-related disciplines. This centre will attract and inspire a new generation of professional ICT researchers. At its core will be a number of world class experts, who will direct the work

programme in consultation with a board of directors. A team of postdoctoral professionals will carry out the work. In order to have the required impact, the minimum viable size for this team is about 200 professionals and we should aim to grow to this size within a three year timeframe.

The centre should not be uniquely associated with any existing university or third level institution, but should have an independent identity and location.

Values

The centre's mission will be to conduct ICT research and development that will be recognised internationally as world class and will be of relevance to industry.

It should not be seen as part of the education system: it should not compete for the funds normally allocated to research in the education system. Rather it should be seen as part of the enterprise sector. It will have a role in technology transfer, in conducting sponsored and commissioned research and in spinning off new companies.

It should be encouraged to develop and foster clusters of actions, networks of contacts and interlocking boards in the same way as in Route 128 in Boston and Silicon Valley in California.

No attempt should be made to restrict the scope of research carried out: research at this level is uniquely dependent on individual vision, empowerment and achievement. It is therefore a programme of investment in excellence.

A board representing industry, government and research interests should agree the work programme. Every effort must be made to engage international experts of the highest calibre on this board, as it is critical for the credibility and ongoing relevance of the centre's work.

The centre's international status should be established as quickly and as definitively as possible. This can best be achieved by seeking partnership with established centres in other countries, such as Massachusetts Institute of Technology, Stanford Research Institute, or University of Washington, whose global role is accepted.

In order to attract the right people, and to carry out work at the required level, projects must have committed funding for at least three to five years. Year-to-year funding is entirely inappropriate for research at this level: it would almost certainly fail to produce significant results and would be singularly unattractive to researchers with the required expertise and reputation.

Education

Education – its quality, quantity, scope and responsiveness – is the single most important ingredient for success. For Ireland to participate in the ICT activities that will be valued in 2015, the education system is the key. We need 'more of the same' and we also need 'something completely different'.

As well as the detailed recommendations outlined in section 3.2, the Panel recommends that a Centre for the Teaching of Science should be established in order to rectify specific deficiencies. Such a centre will need input from educationalists, industry, scientists, psychologists and information designers, as well as subject matter experts.

Market-Led Consortia

The links between publicly funded research in Ireland and the needs of industry are at best tenuous. EU funding mechanisms, notably the Framework programmes, drive the main research agendas. To generalise, the multinational sector would be able to exploit the research, but is unwilling; the indigenous sector is willing, but unable.

In order to improve market links and make the research community more aware of and responsive to the needs of industry, a programme similar to the Israeli BIRD[1] programme should be put in place. This would involve placing a senior executive in a market such as Silicon Valley to represent a consortium of Irish researchers and companies. This person would identify opportunities for contract RTD work and negotiate on the Irish companies' behalf.

Capital Availability and Strategic Guidance

The above actions will increase the number of world class ICT experts in Ireland. However, the ICT industry in Ireland as currently structured - and particularly the indigenous sector - is incapable of absorbing or fully exploiting the talents of such experts. In other countries, such expertise can form the core of fast growing, market-dominating companies. In Ireland, high technology companies tend to grow more slowly. The difference is in two areas: access to risk finance and management expertise.

To ensure that the investment in knowledge and expertise brings commensurate economic returns to Irish society, a different league of venture capital investor is required, with a focus on and an understanding of the high tech sector. One of the top ten US venture capital companies should be encouraged to locate a European operation in Ireland, either alone or in partnership with a local organisation.

Strategic Technologies

As the pace of change in the ICT area is so rapid, it is impossible to predict with any confidence which precise technologies are of long term strategic importance. The Centre for Advanced Informatics proposal is designed to attract and empower the best people, irrespective of the precise area of their expertise. Outside that and in the third level, we need to facilitate a flexible, 'fast follower' approach, where Irish people and Irish industry have the skills needed to adapt and compete in the fast moving environment.

For this, we need to develop skills and expertise at all levels in the population – not only for the survival and growth of industry, but also to enable Irish people to participate fully in the Information Society. Major changes are required at primary, secondary and tertiary levels to foster creativity and imagination from an early age, to provide better teaching of science and mathematics at all levels and to build a commitment by all to life long learning.

Any list of key technologies must be kept under constant review, as the relative importance of topics can change with alarming rapidity. Right now, the following areas are of strategic importance and if Ireland is to be a serious player in ICT, we must develop significant expertise in these areas:

[1] *The Irish Radian programme, operating in the border regions is quite similar in concept but much more restricted in scope.*

Networks: High-speed, broadband, wireless, mobile; voice-data convergence; digital signal processing (DSP); network management; switching (e.g. photonic); Internet 2.

Systems: Distributed, parallel; engineering for reliability, predictability and security.

Components: Integration, miniaturisation, low power consumption; novel architectures.

User Interfaces: Multi-sensory, wearable; virtual reality; artificial intelligence; human language understanding and synthesis.

Applications: Best practices in exploitation and delivery; bioinformatics, telemedicine, health informatics; simulation and modelling; distributed working; supply chain management.

Some of this expertise can be developed at an adequate level in the third level sector. To achieve the required results, some of it must be developed in the new proposed Centre for Advanced Informatics. In either case, we must recognise that the target is constantly moving: whatever institutional responses are made, they must have inbuilt procedures for review, evaluation and modification.

Funding Proposed

In order to make an impact on the scale envisaged, sufficient funding must be in place for about 200 professional researchers over a three to five year period, as well as for the associated measures and VC (Venture Capital) stimulation. The level of State support required for the activities is thus estimated to be some IR£250 million over five years (IR£20 million in year one, IR£40 million in year two, IR£60 million in year three, IR£70 million in year four, IR£60 million in year five). Some funding may be required thereafter, but at that stage the value of the activities, and the return to the State, will be well proven.

Initially, industry's contribution will be in the form of executive time, but, as the research programme begins to yield results and the work programme becomes more embedded in industry, we envisage increased industry participation in funding, both through co-sponsorship and through royalty payments.

1. The Sector Today

1.1 Overview

Information and Communications Technologies (ICT) have become the focal point for competition in products and services throughout the economy. They underpin advances in all areas of economic endeavour from banking services (ATM machines, new transaction products such as charge cards, electronic banking) through manufacturing to healthcare. Even the democratic process itself is being transformed by rapid communication mechanisms.

ICT has been the engine of growth in all the developed economies and Ireland has been no exception. Ireland has been notably successful both in attracting foreign direct investment in the sector and in developing a select number of global companies (Aldiscon/Logica/Act/Kindle, Iona, CBT, Quay Financial/Micrognosis, Trintech).

The limited size of the home market has forced Irish software companies to adopt an export-oriented, product focussed approach. This has been to their benefit and has enabled a number of companies to achieve significant success in foreign markets, particularly in the US.

Existing State resources allocated to developing the sector include the various Programmes in Advanced Technology (PATs): the Software PAT (National Software Directorate and Centre for Software Engineering), Teltec Ireland and other PATs (CIMRU, Power Electronics); the National Microelectronics Research Centre and the application of Structural Funds to the Research Technology and Innovation action. Smaller amounts of annual funding flow on a more 'bottom up' basis through the Strategic Research Grants and similar programmes.

While this general picture is healthy, a number of significant weaknesses are evident:

- Skills shortages have become a central concern of industry
- PC use among the general population is low – less than half the EU average. This contrasts with use by white collar workers, which is the highest in Europe
- The number of main phone lines per 100 population is the lowest in the EU (39 vs EU high of 68)
- Ireland's ICT investment per capita is less than half the EU average and we are the only country in Northern Europe to be below the average[2]. The later timing of our investment, with fewer large data centres, may help to explain this anomaly
- While direct comparisons are difficult, research funding here (from both government and other sources) is considerably lower than in competing nations.

Because of their scale and the limited size of their local market, Irish indigenous companies can succeed only by addressing specific market niches in which they have specialised knowledge of the application area. This implies the need for world class expertise, applications development skills and hybrid professional competence (market awareness, intellectual property management and strategic development). There is concern that sufficient Irish firms are not achieving the growth rate and scale vital to sustainable competitive advantage.

[2] *'Telework 1998, Annual Report from the European Commission*

1.2 ICT in the Irish Economy

reland is categorised as a late developing industrial region, as indicated by the proportion of GDP derived from agriculture and manufacturing industry. The shift towards services - a central characteristic of developed economies - is still taking place here. (In Ireland, 60 per cent of employment is in services; EU highest 74 per cent; EU lowest 56 per cent.)

The contribution of ICT to the Irish economy is readily apparent:

- The sector employed 68,200 people in 1997, representing 5.1 per cent of total employment
- It accounted for 16 per cent of the increase in employment between 1990 and 1997
- Exports from overseas companies in the sector accounted for IR£8.75 billion in 1997
- The sector accounted for 40 per cent of all exports from Ireland in 1997
- Of all new US inward investment to Europe since 1980, Ireland won 40 per cent of investment in electronics, 40 per cent of investment in teleservices, 45 per cent of investment in software and 75 per cent of investment in medical devices. (IDA Ireland, 1996).
- Employment in electronics is expected to grow from 33,000 in 1997 to 62,000 in 2003, an increase of 88 per cent. In software, employment is expected to grow from 19,000 in 1997 to 51,000 in 2003, an increase of 170 per cent. The ICT sector is therefore expected not only to maintain its position as a major employer, but to contribute increasingly to employment creation and to GDP growth.

1.3 ICT in the World Economy

Businesses that produce computers, semiconductors, software and communications equipment have accounted for one third of the total growth in US production since 1992, creating millions of high paying new jobs[3].

Computers amount to only about 2 per cent of the US capital stock, but when all equipment used for transmitting and processing information is added, it amounts to 12 per cent of the capital stock. This is about the same as the railroads at their peak in the late nineteenth century, when they gave a big boost to America's economy[4].

ICT world market growth rates exceeded 9.5 per cent in 1996 and 8.8 per cent in 1997. The value of this market in 1997 was approximately e1,200 billion. Current European growth rates lag behind those of other regions of the world; European market share in 1997 was about 30 per cent, with a tendency towards reduction. By contrast, the US is likely to increase its 35 per cent share.

1.4 Europe in the World of ICT

The ICT market in Europe is almost equally divided between information technology (47 per cent) and telecommunications (53 per cent).

[3] *President's Information Technology Advisory Committee: Interim Report to the President (US), August 1998*
[4] *National Co=ordination Office for Computing, Arlington, U.S.A.*

Hardware represents about 44 per cent of the IT market, IT services (support, consultancy, outsourcing) 35 per cent. Network services show strong growth rates[5].

In telecommunications, there are sharp contrasts, with services and private networks showing good growth, while demand for public networks is growing only modestly. The most promising areas are on-line and value-added services.

Of the top ten developers of administrative software applications in the world, only SAP (Germany) is not based in the US. Leadership in the Enterprise Resource Planning (ERP) market has enabled SAP to invest euro472 million annually in R&D.

On the computer hardware front, only Philips and Siemens are still world players and they have reduced emphasis on hardware production.

In telecommunications, the picture is somewhat brighter, with Alcatel, Ericsson, Nokia and Siemens being among the largest software development organisations in the world.

[5] *European Information Technology Observatory (EITO), EITO 1997 at Hannover.*

2. The Forces of Change

2.1 Introduction

Economic activity, cultural activity, education, healthcare – virtually all aspects of daily life are being changed by ICT. Whole new industries are growing up around ICT; new business models are being realised and old ways of doing business are being rapidly outmoded and made obsolete.

The ICT industries themselves are changing. In particular, we note a trend towards global rationalisation, with mergers and acquisitions, both vertical and horizontal, becoming commonplace.

We also note that the lines between the makers of enabling hardware and software, the suppliers of distribution services and the providers of content are becoming increasingly blurred. The content providers are getting involved in the distribution of the means to view and interact with the content. Entertainment and information industry giants are forging coalitions to exploit new delivery mechanisms.

Telecommunications is primarily a large company activity. There is a minimum size that accommodates sustainable development: the only viable long term strategy (for smaller entrants) is to position the company for acquisition by a larger global player.

By contrast, the software sector in Ireland consists almost entirely of companies that are small by world standards, with average employment less than 30. Only 27 indigenous software companies and 51 overseas software companies in Ireland have more than 50 employees.

It is possible for small companies to survive on the world stage, but we cannot depend on them to create the type of employment growth that the country needs. As the market becomes more global, even the most innovative of such companies are in danger of creating markets that are subsequently exploited by more powerful players.

Global markets demand companies that are capable of operating globally: companies that can identify an opportunity, move fast to dominate the market niche and erect effective barriers to the entry of competitors.

This implies access to the best in venture capital investment (hands-on, aggressive, with a desire for quick development and exit), strategic marketing and ready access to world class expertise[6].

The current health of the ICT industries in Ireland should not lead us into complacency: certain actions must be taken to ensure that the future potential is realised. Some corrections are critical for the survival of the industry, even at its current level:

- ICT-related research is inadequate, both in quantity and quality: we are not encouraging sufficient professionals to pursue a career in research and there is no Irish centre internationally recognised as having world class expertise

6 Venture Capitalists invested an average of $5.8 million in 786 Silicon Valley start-ups in 1998. This level of investment in start-up companies is unheard of in Ireland

- There is a severe shortage of skilled manpower today. Throughput is being increased at undergraduate level, but further resources are needed to increase considerably the number of graduates with expertise in specific disciplines.

The future of the industry in Ireland depends on moving higher up the value chain: using Irish based expertise to design innovative products that have global markets and to control the marketing and strategic aspects of their development, rather than depend on the application of relatively mature technologies and low value-added services. This approach is widely favoured by the industry and has been promoted, among others, by the Irish Software Association (To Boldly Go…The Irish Software Industry: a Strategy for Growth, 1998).

This approach has two requirements that cannot be satisfied from within the current industry or the current support mechanisms: it needs companies of sufficient scale and it needs a greatly enhanced research and development environment.

Growth to the size necessary for global operation and market dominance – and particularly fast growth – cannot depend on retained earnings. The company must be willing and able to attract successive rounds of venture capital prior to stock market flotation and the venture capital providers must be familiar with high-technology companies and the markets in which they operate. Steps must be taken to improve the venture capital climate in Ireland so that sufficient funds (and the accompanying expertise) are available.

Venture capital companies continually state that they select people rather than business plans for investment. This again emphasises the need to complement the development of technical expertise with the development of non-technical skills such as team building, finance, marketing, sales and project management and to nurture the development of interdisciplinary teams.

2.2 Technologies

It is not possible to predict specific technologies that will be relevant over the 17 year time horizon of the Foresight exercise. Some of the current pre-commercial research work around the world could have significant impacts on the ICT markets if it proves to be robust and is commercialised. The minimum requirement for the Irish technological capacity is to monitor such developments and maintain sufficient expertise in the relevant disciplines so that we can respond to changes as they come along and adapt our products, processes and services to the new environment. Examples of such developments include:

- *Quantum computing,* which involves the application of quantum physics to the problem of designing more powerful processors, high density storage and high speed switching
- *DNA computing,* which uses the insights and techniques of the bio-molecular revolution to build extremely fast, massively parallel processors that are designed and built to solve a single problem; while their range of application and commercial potential is (apparently) limited, DNA computers could create and fill a unique niche in the overall ICT industry
- *Molecular nanotechnology,* which involves manipulating individual atoms to build extremely small devices. This area is attracting major investment around the world and, while there is still no guarantee that it will ever be successfully commercialised, its potential impact is such that it has been called the ‘greatest technological breakthrough in history’

- *Bioinformatics,* medical informatics, MEMS: ICT is making a major contribution to the understanding of biological processes, to medical product development and to the delivery of health services. Many such projects in academia and the commercial sector demand a combination of skills and expertise from the life sciences, information technology and mechanics
- *Software engineering,* which is still a relatively young discipline that demonstrates its immaturity in most commercial software packages and in some spectacular failures. The market understandably demands predictable performance, reliability and security in mission critical applications. Much effort is being expended in trying to develop methods, procedures, tools and techniques to meet this demand.

Monitoring international developments and maintaining a broad capability for rapid response is the key to success in this rapidly changing environment: we cannot hope to be at the forefront of all these developments. Against a broad, general ICT capability, specific expertise can then be built with a shorter time horizon. Such expertise needs to be world class and have committed linkages to peers in other parts of the world.

Instead, therefore, of a recommended set of technologies that will have relevance over a 17 year period, we suggest a rolling five year programme that will constantly revise its priorities in the light of the current state of the art. The areas of immediate concern include:

Networks: High-speed, broadband, wireless, mobile; voice-data convergence; digital signal processing (DSP); network management; switching (e.g.photonic); Internet 2.

Systems: Distributed, parallel; engineering for reliability, predictability and security.

Components: Integration, miniaturisation, low power consumption; novel architectures.

User Interfaces: Multi-sensory, wearable; virtual reality; artificial intelligence; human language understanding and synthesis.

Applications: Best practices in exploitation and delivery; bioinformatics, telemedicine, health informatics; simulation and modelling; distributed working; supply chain management.

Ireland needs to develop significant expertise in these areas if it is to be a serious player in ICT over the coming decade.

It is also clear that areas of great opportunity are at the boundaries between disciplines that have traditionally been discrete. The convergence of computing and telecommunications and the resulting commercial opportunities have been well documented, but many other such areas are emerging. Developments in artificial intelligence, for example, require the concerted action of computer scientists, psychologists, mathematicians and other specialists; new entertainment products (and other multimedia, computer-based training and consumer services) require teams of writers, designers, artists, marketing specialists and psychologists; many business-to-business services require new skills as they move from their traditional delivery modes to the new electronic media.

This development of multi-talented individuals and interdisciplinary teams is not something that our education system is designed to encourage.

2.3 Political Climate

The political climate in Ireland for industrial development has never been better. There is a tangible air of optimism and confidence, bolstered by effective action in many 'bottleneck' areas such as telecommunications competition and costs.

Initiatives such as the Information Society Commission, the Office of Director of Telecommunications Regulation and the Telecommunications Advisory Committee[7] have heightened awareness of the key infrastructural issues in Ireland and how they should be addressed. There is considerable agreement between the main political parties and the social partners in relation to industrial development and the economy. This has led to a stable investment environment.

Ireland's joining of EMU has also had a stabilising effect on the investment environment, with currency risk being removed from the set of variables for investors.

2.4 Competitive Trends

Throughout the world, organisations are trying to reduce costs. The effective application of ICT has been a major contributor to this process, with many organisations using enterprise-wide, integrated planning, management and control software and systems, even extending their systems to their networks of suppliers and customers.

Particularly in relation to goods and services with a high knowledge content, the world market has become integrated. Products of even smaller companies have to be designed for a world stage. Several Irish software companies have recognised this and have designed their products to support foreign character sets, so that, for example, they can be easily localised for the Japanese and Chinese markets.

Scale is also an issue: economies of scale are not only realised in the administrative, marketing and sales functions; a company must also have a range of products and have the capacity to respond quickly and effectively to shifts in competition, technology or customer demand.

2.5 Growth of the Economy

Because Ireland's economy is very open, our long term success is inextricably linked to the growth rates of our main export markets and our competitive position in relation to them. Thus, while the near term growth in Irish GDP is forecast at over 8.0 per cent per annum, the growth rates in the main European, US and other markets are significantly lower and are of more direct concern. Indeed, any overheating of the local economy can have an adverse effect on all the factors of production, especially wage costs.

The initial effects of this in terms of skill shortages and wage inflation are already evident. About 2,000 software jobs are vacant at present (approximate employment noted as 29,700 total in a recent study). Some Irish companies recently decided to set up development activities in India, instead of further developing their Irish operations. Wage inflation and other cost increases were certainly influential in these decisions.

7 Report of the Advisory Committee in Telecommunications to the Minister for Public Enterprise, November 1998.

With a good balance of payments position and a positive economic outlook, we can position ourselves to thrive even in a future, more challenging business environment if we invest wisely now in the telecommunications infrastructure and in research and development.

2.6 Environmental Considerations

The ICT industries have a good environmental record. The industries covered are not major contributors to pollution. Indeed, they have a strong contribution to make towards sustainable development. An economy based on 'bits not atoms' (Negroponte) is attractive and scaleable without an overpowering pollution load.

ICT can make a positive contribution to other industries by driving new business models, through reducing energy in production and distribution and through facilitating the 'extended enterprise' including teleworking.

ICT also contributes to environmental monitoring and remediation and to many aspects of societal health and well-being. The Human Genome Project, for example, would be impossible without medical informatics. At a more operational level, the management of the healthcare system offers tremendous scope for effective implementation of ICT, especially in Ireland.

2.7 Demographic Trends

Any projection of population and workforce over a long time period has to be tempered with a note of caution: there are very large uncertainties involved, such as emigration and immigration, the participation of women in the labour force and changes in birth rates. Some broad conclusions can be drawn from recent analyses:

- Agricultural employment will continue to decline over the next 15 years, with the corresponding need to create significant employment in industry and services. The services sector is expected to provide the main source of employment opportunities
- Despite the fact that the 'baby boom' bulge is passing through the 10 to 14 year age group, there is strong potential for building an educated and flexible work force over the years to 2015
- Net migration can have a particularly large effect on Ireland. Dramatic shifts have occurred in recent times: between 1971 and 1981, net inward migration was 10,400 per annum, while between 1986 and 1991, net outward migration was 26,900 per annum. Such shifts could be explained by relative economic performance. In the (unlikely) event that zero net migration occurred over the period to 2010, there would be an additional 134,000 in the labour force.

Migration alone could therefore impact the labour force estimates by plus or minus 8 per cent.

2.8 Predictability, Confidence, Uncertainty

The Panel did not try to predict the future: it was concerned with preparing for the future, no matter what precise future comes along.

The methodology employed by the Panel in analysing the strengths and weaknesses of the Irish ICT sector, and in identifying the opportunities and threats it faces, was designed to produce recommendations that were robust: their implementation will make a positive contribution to the prosperity of Irish society, irrespective of the precise changes in the political, technological or market environment. The converse is also true: failure to implement these strategies will lead inexorably to a decline in the sector and missed opportunities for societal benefits.

3. Recommended Strategies

Recommended Strategies

The ICT Technology Foresight Panel focussed its efforts on answering the following strategic question:

How will Ireland be able to participate in the ICT activities that will be valued in 2015?

In order to find some answers to the question, the group had to consider which ICT activities - goods and services - would be valued. This implied consideration of what society will be like in 2015 and what its values and aspirations will be.

The two aspects of the question then came into focus:

- How can Irish society participate as *consumers/users* of these goods and services?
- How can Irish society participate as *producers* of these goods and services?

Where uncertainties in the environment prevent these questions from being answered in a concrete way - and the rapid pace of technological development alone makes it very difficult to be precise - the Panel considered how our national positioning - in terms of social policies, educational policies, industrial policies, cultural policies and so on - can be strengthened so that we can succeed in any case.

The Panel was unanimous in identifying the development of human capital at all levels as the priority in preparing for the future.

Indigenous firms, in order to compete on a world stage, need to move up the value chain and produce goods and services with a higher intellectual content. This depends on their ability to create new technologies and to work at the state-of-the-art. Similarly, if we are to encourage the multinational companies to deepen and strengthen their presence here, we have to facilitate them to carry out the higher value-added functions, including basic research and new product development. Again, this depends on the availability of world class expertise. And, given that the market for production activities is a global one, our ability to attract further foreign direct investment will depend on our being able to offer something different: and scarce expertise is almost irresistible from that point of view.

Expertise is needed at several levels, following a ‘pyramid’ model.

- World class experts in a select number of disciplines at the apex
- Professionals with high level skills
- Vocational competence in core technologies and cross disciplinary skills
- A broad base of citizens who are comfortable with ICT and who participate freely and easily in the Information Society.

The pyramid model illustrates a number of important considerations. First, it highlights the fact that we cannot grow a cadre of world class experts in isolation: such expertise depends crucially on, and grows out of, the levels below and ultimately from the broad population. It also shows that the relative numbers required at each level is different: a small number of world class experts can create opportunities for a much greater number of competent

professionals. And it shows that development is not exclusive to the people at the apex: growth in the absolute size of the pyramid has positive benefits for the whole society, reflecting the distribution of abilities in the society.

3.1 Centre of Expertise

The critical new aspect of the pyramid model of skills is the apex: it is absolutely essential that Ireland develop a highly visible critical mass of world class expertise in ICT.

It is essential for the survival and growth of the indigenous sector; it is essential to embed the multinationals in this country; and it is essential to attract further foreign direct investment.

The required development is different in kind and in scale from anything currently in the country.

We envisage a *Centre for Advanced Informatics*, led by a small number of world renowned experts, staffed by professional postdoctoral researchers, carrying out leading edge research at a level where they can make an impact.

Experts of the required calibre will be attracted to work in this centre only if:

- They are in a stable, productive, visionary environment
- They are surrounded by a number of their peers
- They have access to the latest and best equipment
- They have committed financial support for a reasonable time period
- They have sufficient backup and support staff
- The location and facilities are first rate
- They have reasonable intellectual freedom to pursue their enquiries
- They are remunerated at internationally competitive rates.

However, if we *do* attract such people, they will in turn attract the best young researchers to work with them and this will have a catalytic effect throughout the skills/knowledge pyramid and into industry.

The centre's mission will be to conduct ICT research and development that will be recognised internationally as world class and will be of relevance to industry. It is almost immaterial what precise technology areas are addressed in the centre: what matters is the quality of the work. We should therefore start by identifying the key people, rather than by defining the technology remit.

The centre will operate under a board of directors, which will include representatives of industry, the universities and the State. Special effort must be made to engage international experts of the highest calibre on this board, as it is critical for the credibility and continuing relevance of the centre's work.

The board will also enable the centre to develop and foster clusters of actions, networks of contacts and relationships with other institutions and companies, in the same way as happens in similar institutions elsewhere.

The centre's international status should be established as quickly and as forcibly as possible. This can best be achieved by seeking formal partnership arrangements with established centres in other countries, such as MIT, SRI, or University of Washington. The global role of these centres is well accepted.

In order to have the required impact, the minimum viable size for this team is about 200 professionals and we should aim to grow to this size within a three year timeframe.

Although it has a role in the development of skills and expertise, the centre should not be seen as part of the education system: it should not compete for the funds normally allocated to research in the education system. Rather it should be seen as part of the enterprise sector: it will have a role in technology transfer, in conducting sponsored and commissioned research and in spinning off new companies.

The centre should not be uniquely associated with any existing university or third level institution, but should have an independent identity and location.

In order to attract the right people and to carry out work at the required level, projects must have committed funding for at least three to five years. Year-to-year funding is entirely inappropriate for research at this level: it would almost certainly fail to produce significant results and would be singularly unattractive to researchers with the required expertise and reputation.

Initially, industry's contribution will be in the form of executive time, but, as the research programme begins to yield results and the work programme becomes more embedded in industry, we envisage increased industry participation in funding, both through co-sponsorship and through royalty payments.

After five years some State funding might still be required, but at that stage the value of the activities and the return to the State will be well proven. Any measure of performance must take into account the influence of the centre throughout the education system and industry, the heightened visibility and attractiveness of Ireland as a location for foreign direct investment and the spin-off of new companies.

The focus technologies should be decided on a rolling basis by the board of the centre, in consultation with the key personnel. Initial target technologies could be chosen from:

Networks: High-speed, broadband, wireless, mobile; voice-data convergence; digital signal processing (DSP); network management; switching (e.g. photonic); Internet 2

Systems: Distributed, parallel; engineering for reliability, predictability and security

Components: Integration, miniaturisation, low power consumption; novel architectures

User Interfaces: Multi-sensory, wearable; virtual reality; artificial intelligence; human language understanding and synthesis

Applications: Best practices in exploitation and delivery; bioinformatics, telemedicine, health informatics; simulation and modelling; distributed working; supply chain management.

2.3 Political Climate

The political climate in Ireland for industrial development has never been better. There is a tangible air of optimism and confidence, bolstered by effective action in many 'bottleneck' areas such as telecommunications competition and costs.

Initiatives such as the Information Society Commission, the Office of Director of Telecommunications Regulation and the Telecommunications Advisory Committee[7] have heightened awareness of the key infrastructural issues in Ireland and how they should be addressed. There is considerable agreement between the main political parties and the social partners in relation to industrial development and the economy. This has led to a stable investment environment.

Ireland's joining of EMU has also had a stabilising effect on the investment environment, with currency risk being removed from the set of variables for investors.

3.2 Education

Education – its quality, quantity, scope and responsiveness – is the single most important ingredient for success. For Ireland to participate in the ICT activities that will be valued in 2015, the education system is the key. We need 'more of the same' and we also need 'something completely different'.

More of the same is necessary because Ireland's system of broad-based secondary education is an important differentiator: we produce a large number of young adults every year who have some knowledge of languages, history, geography, mathematics, art and music and the sciences. This broad base upon which the third level education system can build is agreed to be one of Ireland's strengths; it contributes to the adaptability and flexibility of the workforce -qualities that will be increasingly important in the years ahead. However, the recent decline in the uptake of the hard sciences at secondary level and in particular the declining numbers of students opting for higher level courses in mathematics and physics is of concern.

Something completely different is necessary if we are to respond to the major changes in the environment.

At **primary** level:

- Introduce science, mathematics and logic at an early age, in such a way that all pupils are comfortable with basic science and mathematics
- Foster critical skills and evaluation. These skills are essential for effective functioning in an environment in which more information of uncertain quality is available from a multiplicity of channels
- Encourage pupils to ask questions and to adopt a problem solving approach
- Give priority to additional manpower (reduced pupil/teacher ratio, remedial teaching, nurture exceptional talent) and basic infrastructure (school buildings).

At **secondary** level:

- Continue with a broad based Leaving Certificate
- Foster problem solving, imagination, innovation, lateral thinking, independence, rather than memory and 'right answers'. This may require a radical overhaul of the points system
- Give priority to additional equipment (for information access and laboratories), connectivity and delivery of a wider range of subject choice (using appropriate technology).

At **third** level:

- Continue to deliver good primary degrees in all disciplines
- Recognise part-degrees and multi-discipline (modular) degrees
- Provide for flexibility in moving into and out of employment throughout courses
- Recognise that education must become more integrated with all aspects of life and continue throughout life
- Make a serious commitment to postgraduate research, with adequate funding
- Facilitate cross-discipline and multi-discipline research and development. Create a special R&D fund (maybe even a physical institution) which will invite applications from different disciplines, different institutions and industry-university teams; make awards based on innovativeness; administered with strong involvement of industry representatives
- Establish industrial liaison boards with power to review and influence the redesign of curricula
- Make provision for short modules in final years, to be established in response to immediate needs. Similarly, provide modules for conversion courses and in-service training
- Review and streamline curriculum procedures to ensure flexibility and speed of response.

The requirements at primary and secondary level highlight the scarcity of teachers with science, technology and engineering qualifications. Incentives must be introduced to attract science graduates into teaching. One possible mechanism would be to offer a teaching module (with work experience) in all science related degrees.

The problem is not confined to Ireland. If we were to build expertise in the teaching of science, mathematics and information technology, that expertise, apart from having an immediate and direct impact on skill levels in Ireland, would have a global market. The curricula, course materials, Computer Based Training (CBT) and distance learning materials and even the courses (delivered electronically) could all be sold to other countries which are anxious to develop the skills of their young people.

The Panel recommends that a **Centre for the Teaching of Science** should be established to pursue these objectives. Such a centre will need input from educationalists, industry, scientists, psychologists and information designers, as well as subject matter experts. We would emphasise that the problem is not simple: the correct interventions at the right time in a

young person's development can make a lasting difference; similarly, a poor introduction to a subject can create an irreversible bad impression.

3.3 Wired Country

Pervasive, high speed, low cost access to information services is a basic requirement for participation in the information age, either as a consumer or as a producer. Without low cost bandwidth availability throughout the country (both in homes and in businesses), Ireland will not be able to participate in the ICT activities that will be valued.

This pervasive, high speed, low cost access is needed to ensure:

- Social equity, the realisation of human potential, the avoidance of social disruption
- The delivery of education and training in a distributed, low cost, lifelong model
- Success of the ICT industry in developing products and services
- The survival of all industry that wants to do business in Ireland
- The growth of teleworking, with its attendant environmental and economic advantages
- Effective participation in democratic decision making at all levels.

A proactive approach to investment in telecommunications is also necessary to position the country as a good location for foreign investment in telecommunications-dependent businesses. This implies that the investment must anticipate the demand, rather than simply respond to it.

Other documents have made the case for such investment and have dealt comprehensively with the physical connectivity requirements, the social inclusion considerations and the regulatory environment. The Panel endorses the overall thrust of the recommendations in:

- *Telecommunications Priorities - An Agenda for Government and Regulation,* Irish Business and Employers Confederation
- *First Report* and subsequent work, The Information Society Commission
- *Broadband Telecommunications Investment in Ireland,* Forfás
- Recommendations of the Advisory Committee on Telecommunications.

These reports (and others) make convincing arguments for specific, immediate actions: any delay in implementation will be detrimental to the country's economic development.

3.4 Venture Capital

The development of the indigenous sector is limited by the shortage of venture capital (VC) and in particular of the kind of venture capital that is found in other high technology centres - capital that is hungry for fast growth and that supports its investments with expertise and contacts. For example, although the ICT sectors in Ireland and Israel are comparable (in terms of company size, numbers employed, turnover and export performance), Israeli companies are growing faster and very many more have been floated publicly, giving them access to very substantial funds for product development and marketing. Similarly, 'high

growth start-ups' in California routinely employ 200 people within two years: this pace is unheard of in Ireland.

A more proactive venture capital climate is needed in Ireland in order to ensure that the investment in knowledge and expertise brings commensurate economic returns to Irish society. We need to attract venture capital organisations to this country – ones who can focus on, and who understand, the high-tech sector. At least one of the top ten US VC companies should be encouraged to locate a European operation in Ireland, either alone or in partnership with a local organisation.

3.5 Strategic Intelligence

Because of the scale of most Irish companies, the small size of the local market and the corresponding need to be aware of and responsive to developments in markets and technology, market intelligence must be gathered and disseminated in a more systematic fashion. A technology watch or radar programme should be put in place to identify those areas of technology which are moving fast towards commercialisation and on changes in the attitudes of society and consumers to their applications.

Similarly, in order to improve market links and make the research community more aware of and responsive to the needs of industry, a programme similar to the Israeli BIRD[8] programme should be put in place. This would involve placing a senior executive in a market such as Silicon Valley to represent a consortium of Irish researchers and companies. This person would identify opportunities for contract RTD work and negotiate on the Irish companies' behalf.

3.6 Nurture the Diaspora

Around the world, but particularly in the US, there are a great many people who have emigrated from Ireland or who are of Irish descent. Over 44 million Americans claim Irish roots. Many of these people are in highly influential positions: 25 per cent of the major US multinationals have Irish-American CEOs. For the most part, these people are well disposed towards Ireland and would welcome the opportunity of contributing to its development.

Two immediate lines of action recommend themselves:

- We should foster strategic alliances between Irish companies and US companies, following the model outlined in *To Boldly Go*[9]. Such alliances could include investment, subcontracting, contract research and/or development, sharing of market knowledge, transfer of business acumen and opening up of contacts. In this context, note that the US market is central to the success of software products in particular
- In seeking to raise the level of expertise in Ireland and in trying to address skill shortages at every level, we should try to attract back to Ireland people who have left and particularly those with experience and skills in the target areas. Clearly recent emigrants and people who feel 'at home' in Ireland will be more likely to stay here once attracted back.

8 The Irish Radian programme, operating in the border regions is quite similar in concept but much more restricted in scope.
9 To Boldly Go.... The Irish Software Industry - A Strategy for Growth, Irish Software Association, 1998.

3.7 State Funding Proposed

Dedicated public funds are required to implement the Centre for Advanced Informatics and, to a lesser extent, to seed the new approach to venture capital. The level of state support required is estimated to be some IR£250 million over five years (IR£20 million in year one, IR£40 million in year two, IR£60 million in year three, IR£70 million in year four and IR£60 million in year five).

Appendix I - ICT Panel Members

Paul Holden Chairman	Managing Director	Redacteurs Documentation Ltd
Frank Turpin, Deputy Chairman	Academic Relations Manager	Intel Ireland Ltd
Frank Boland	Professor	Electronic & Electrical Department The University of Dublin, Trinity College
Eamon Cahill	Consultant	Irish Productivity Centre
Jennifer Condon	Director	National Software Directorate, Enterprise Ireland
Joe Curtis	Director	Teltec Ireland PAT, Enterprise Ireland
Hilary Louis Doyle	General Manager	GATT, Centre for Advanced Technology Training
Edwina Fitzmaurice	General Manager	Scottish Amicable Ireland Ltd
David MacDonald	Chief Executive Officer	I.T.P. Ltd
Tony McGuire	Managing Director	System Dynamics Ltd
Susan McKenna Lawlor	Professor	Department of Experimental Physics, NUI - Maynooth
Danny McLoughlin	Managing Director	Visibility Software Ltd
Denis Molumby	Manager	International & Financial Services, IDA Ireland
Jim Mountjoy	Managing Director	Euristix Europe Ltd
Barry Murphy	Manager	Cullinane Group Ireland
Pat O'Connor	Managing Director	IISL Ltd (IBM Ireland)
Diarmuid O'Colmain	General Manager	Ericsson Systems Expertise Ltd
Michael Ryan	Professor	School of Computer Applications, Dublin City University
Frank Ryan	Manager Electronics	Electronics & Enginneering Division, IDA Ireland
John Sterne	Managing Director	Newsmail Ltd
George Young	Director	Commergy Ltd
Martin Hynes	Secretariat	Science, Technology and Innovation Division, Forfás

Appendix II - Workshop Participants

Consultative Workshop 20th and 21st October 1998	
Eamon Cahill	Irish Productivity Centre
Robert Cochran	Centre for Software Engineering, DCU
Jennifer Condon	National Software Directorate, Enterprise Ireland
Dermot Costelloe	Boole & Baggage Europe Ltd
Gabriel Crean	National Microelectronics Research Centre, UCC
Joe Curtis	Teltec PAT, Enterprise Ireland
Edward J. DeGroot, FCA	Consultant
Michael Donnelly	Innovation Centre, CityWest
Paula Downey	Downey & Youell Communications
Hilary Doyle	Siemens Nixdorf Ireland Ltd
Ian Dunlop	Lotus Development Ireland
Edwina Fitzmaurice	Scottish Amicable
Shay Garvey	Delta Partners Ltd
Seamus Grimes	Department of Geography, NUI Galway
Gerry Hennigan	Goodbody Stockbrokers
Paul Holden	Rédacteurs Software Documentation Limited
Martin Hynes	Science, Technology and Innovation Division, Forfás
Edna Jordan	Irish National Teachers Organisation
Dick Kavanagh	Combined Circuit Manufacturers Ltd
Annette Kelly	An Chomhairle Leabharlann
Maura Leydon	Association of Secondatry Teachers of Ireland
Madeline Lyons	Business & Finance Magazine
Mattie McCabe	Department of Enterprise, Trade & Employment
Darach McEvoy	Quaestus International Limited
Tony McGuire	System Dynamics Ltd
Susan McKenna-Lawlor	NUI Maynooth
Des McLoughlin	Telecom Eireann
Eamonn McQuade	University of Limerick

Richard Mulcahy	Systems Solutions Software Ltd
Brendan Munnelly	Rédacteurs Software Documentation Limited
Barry Murphy	Cullinane Group Ireland
Colm Nolan	NEC Semiconductors Ireland
Michael O'Brien	Dublin Business School
John O'Brien	Silcon & Software Systems
Diarmuid O'Colmain	Ericsson Systems Expertise Ltd
Pat O'Connor	ISL Ltd, (IBM Ireland)
Michael O'Duffy	Centre for Software Engineering
Brendan O'Regan	ESBI Computing Ltd
Barry O'Reilly	Engineering Solutions International Ltd
Michael Pender	Department of Enterprise, Trade & Employment
Michael Ryan	Dublin City University
Alan Smeaton	Dublin City University
John Sterne	Newsmail Ltd
Frank Turpin	Intel Ireland Ltd
John Wright	Databank Systems Ltd
George Young	Commergy Ltd

Appendix II - Submissions Relevant to the Work of the ICT Panel

Dr. Gabriel Crean	NMRC, Future Trends in Microelectronics and other feedback.
Dr. Seamus Grimes	NUI Galway: "IT-related Foreign Direct Investment in Ireland: an integrated policy or short term strategy?" "Rural areas in the Information Society: diminishing distance or increasing learning capacity?" and other comments.
Dr. Dick Kavanagh	IRDG and Combined Circuit Manufacturers Ltd. Informal feedback at the **Irish Research Scientists Association** summer school venue.
Mr. John Moore	Terenure: "Office of Innovation" paper and other comments.
Dr. Paddy Nixon and Dr. Vinny Cahill	University of Dublin, Trinity College: "The future of Business is Virtual".
Pierce Martin & Michael O'Donnell	Institution of Engineers of Ireland: Critique on ICSTI Technology Foresight.

Other Inputs

As well as these written submissions a number of direct interviews and informal e-mail interchanges took place over the consultation period.

The Foresight web site had about 3,000 visitors (66,000 hits) and around 150 people registered an interest in the discussion forum on that site.